

Pseudoaneurysms of the Mitral-Aortic Intervalvular Fibrosa: Dynamic Characterization Using Transesophageal Echocardiographic and Doppler Techniques

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Objectives. The aim of this study was to provide a detailed description of echocardiographic and Doppler features of pseudoaneurysms involving the mitral-aortic intervalvular fibrosa and to compare echocardiographic and aortographic findings.

Background. Infection of the aortic valve may spread to the aortic annulus, resulting in ring abscesses or pseudoaneurysms, or both, of the intervalvular fibrosa, which can alter patient management and prognosis.

Methods. The echocardiographic and Doppler findings of 20 patients with pseudoaneurysms or ring abscesses, or both, were reviewed and compared with surgical and aortographic results.

Results. A total of 23 lesions were identified, of which 16 were intervalvular pseudoaneurysms, and 7 were ring abscesses. Transthoracic echocardiography detected 43% of the lesions, whereas transesophageal echocardiography identified 90% ($p < 0.01$). The most distinct feature of the pseudoaneurysms was marked pulsatility, with systolic expansion and diastolic collapse (mean systolic area $[\pm \text{SD}]$ $4.1 \pm 3.4 \text{ cm}^2$ vs. diastolic mean area $1.8 \pm 2.2 \text{ cm}^2$, $p < 0.05$). Using color Doppler, two types were identified: unrup-

tured pseudoaneurysms ($n = 9$), which communicated only with the left ventricular outflow tract and had a distinct flow pattern, and ruptured pseudoaneurysms ($n = 7$), which, in addition, communicated with the left atrium or aorta. Compared with pseudoaneurysms, ring abscesses were smaller and nonpulsatile and showed either no flow or continuous systolic and diastolic flow, the site of paravalvular aortic insufficiency. In 10 patients who underwent aortography, three lesions were identified, and findings were concordant with echocardiography. However, in seven patients aortographic findings were normal, whereas echocardiography identified intervalvular pseudoaneurysms, all of which were documented at operation.

Conclusions. Intervalvular pseudoaneurysms are more frequently detected by transesophageal echocardiography than by aortography or transthoracic examination and exhibit distinct dynamic features and Doppler patterns that can further help characterize cavitory lesions in the aortic root and guide appropriate surgical intervention.

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Infection of the native or, more commonly, prosthetic aortic valve may spread to the aortic ring, producing abscesses (1-3). Although these complications may involve any part of the aortic ring, posterior lesions have been shown (4,5) to frequently affect the mitral aortic intervalvular fibrosa, a region of fibrous tissue where the anterior mitral leaflet becomes continuous with the aortic ring. Infection or even trauma may produce a dehiscence in this region that results in the formation of an abscess or a pouch between the medial wall of the left atrium and the aorta. An intervalvular pseudoaneurysm

ensues when this abscess or pouch communicates with the left ventricular outflow tract (5-8). Complications of intervalvular pseudoaneurysms may include rupture of the pseudoaneurysm into the left atrium, aorta or even pericardial sac, with ensuing cardiac tamponade and death (5,8,9). Accurate detection and delineation of intervalvular pseudoaneurysms and differentiation from ring abscesses is therefore crucial in overall patient management and in surgical guidance because, as a result of their location, the pseudoaneurysms may not be readily identified at operation.

Since the initial description in 1966 of an intervalvular pseudoaneurysm diagnosed at angiography, few cases detected by echocardiography, angiography or magnetic resonance imaging have been reported (10-12). With the advent of transesophageal echocardiography, improved visualization of basal cardiac structures is achieved that may enhance detection and assessment of intervalvular pseudoaneurysms (13,14). To date, there is a paucity of data as to the Doppler echocardiographic characteristics of intervalvular pseudoaneurysms (14-16). Furthermore, no comparison of echocardiographic and angio-

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Table 1. Clinical Data and Echocardiographic, Angiographic and Surgical Findings in 20 Patients With Pseudoaneurysms of the Mitral-Aortic Intervalvular Fibrosa or Aortic Ring Abscesses, or Both

Pt No.	Age (yr)/Gender	Aortic Valve	Clinical Dx	Lesion	Echocardiographic/Doppler Findings				Commun	Associated Regurgitation	Aortographic Findings	Surgical Findings
					Dx by TTE	Dx by TEE	Systolic Area (cm ²)	% Area Change				
1	69/M	BS	PrV dysfunction	MAIVF An	No	Yes	1.1	100	LVO	None	ND	ND
2	36/M	St. Jude	PrV dysfunction	MAIVF An	No	Yes	1.4	100	LVO	None	Normal PrV	MAIVF An
3	65/M	St. Jude	Endocarditis	MAIVF An	?	Yes	5.1	18	LVO	None	ND	MAIVF An
4	66/M	SC	PrV dysfunction	MAIVF An	No	Yes	0.7	57	LVO	None	Normal PrV	MAIVF An
5	44/M	St. Jude	Endocarditis	MAIVF An	Yes	Yes	4.5	89	LVO	None	Normal PrV*	MAIVF An
6	62/M	St. Jude	Endocarditis	MAIVF An	No	Yes	1.5	100	LVO	AI	MAIVF An, AI	MAIVF An
7	55/M	St. Jude	TIA	MAIVF An	ND	Yes	5.0	90	LVO	None	Normal PrV	MAIVF An
8	31/M	DeBakey	Endocarditis	MAIVF An	Yes	Yes	12.5	48	LVO	None	Normal PrV	MAIVF An
9	32/M	St. Jude	PrV dysfunction	MAIVF An	Yes	Yes	7.7	26	LVO, Ao	AI	ND	MAIVF An
10	37/F	Native	CHF, endocarditis	MAIVF An	Yes	Yes	3.2	6	LVO, Ao	AI	ND	MAIVF An
11	33/M	St. Jude	Endocarditis	MAIVF An	ND	Yes	9.1	51	LVO, Ao	AI	MAIVF An, AI	MAIVF An
12	45/M	DeBakey	Endocarditis	MAIVF An	No	Yes	0.8	100	LVO, LA	MR	ND	ND
13	61/M	Medtronic	Endocarditis	MAIVF An	No	Yes	1.1	100	LVO, LA	MR	Normal PrV	MAIVF An perforated into LA
14	45/M	Homograft	Endocarditis	MAIVF An	Yes	Yes	4.9	55	LVO, LA	MR	Normal PrV*†	MAIVF An perforated into LA
15	55/M	St. Jude	Endocarditis	MAIVF An	No	Yes	2.2	61	LVO, Ao	AI	ND	MAIVF An and ring abscess
16	55/M	CE	Endocarditis	Post ring abscess	No	Yes	2.2	0	None	None	ND	Multiple ring abscess
				Ant ring abscess	Yes	?	2.3	-4	LVO, Ao			
				MAIVF An	Yes	Yes	5.3	73	LVO			
17	49/F	Porcine	Endocarditis	Post ring abscess	No	Yes	0.3	19	None	None	ND	Ring abscess
18	47/M	St. Jude	Endocarditis	Post ring abscess	Yes	Yes	3.5	-2	None	None	ND	Ring abscess
19	53/M	Native	Endocarditis	Ant ring abscess	Yes	?	2.2	12	LVO, Ao	AI	Ring abscess, AI	Ring abscess
20	37/M	St. Jude	Endocarditis	Ant ring abscess	?	Yes	1.3	0	LVO, Ao	AI	ND	Multiple ring abscesses
				Ant ring abscess	?	Yes	1.2	0	LVO, Ao			

*Mitral-aortic intervalvular fibrosa pseudoaneurysm (MAIVF An) on left ventriculography. †Mitral regurgitation (MR) on left ventriculography. AI = aortic insufficiency; Ant = anterior; Ao = aorta; BS = Bjork-Shiley; CE = Carpentier-Edwards; CHF = congestive heart failure; Commun = communications; Dx = diagnosis; F = female; LA = left atrium; LVO = left ventricular outflow tract; M = male; ND = not done; Post = posterior; PrV = prosthetic valve; Pt = patient; SC = Smeloff-Cutter; TEE (TTE) = transesophageal (transthoracic) echocardiography; TIA = transient ischemic attack.

graphic findings of intervalvular pseudoaneurysms has been performed. In the present study, two-dimensional and Doppler techniques were applied to assess the size, physiologic behavior and flow dynamics of intervalvular pseudoaneurysms. Characteristics that differentiate these pseudoaneurysms from ring abscesses are described. The echocardiographic findings are compared with surgical and angiographic results in a subset of patients who underwent both tests.

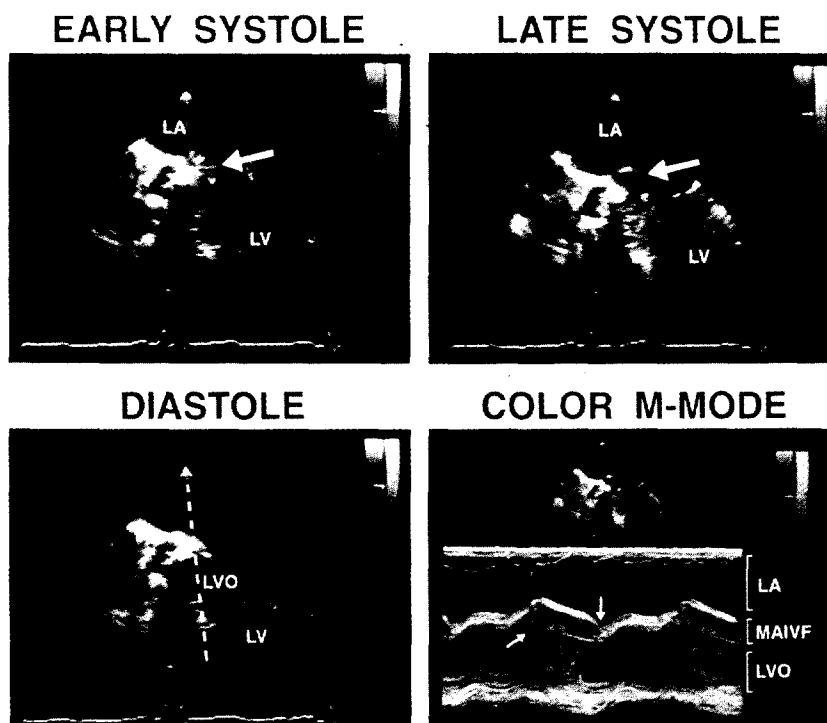
Methods

Patients. Since the first identification of an intervalvular fibrosa pseudoaneurysm by transesophageal echocardiography in our institution in February 1989, all patients with cavitary lesions in the region of the intervalvular fibrosa or the aortic ring, or both, identified by echocardiography (transthoracic or transesophageal, or both) underwent a comprehensive echocardiographic and Doppler examination (see later). A total of 20 patients were identified between February 1989 and February 1993. All 20 patients underwent transesophageal echocar-

diography, including those with definite or suspected lesions on transthoracic examination (n = 12). During this period, 818 patients had undergone transesophageal studies at our institution. In 164 patients, it was performed for suspected aortic valve or ring disease, or both. Patients with pseudoaneurysms complicating composite aortic grafts were not included and have been recently discussed elsewhere (17).

Clinical characteristics of the patients are shown in Table 1 (18 men, 2 women; mean age 50 years, range 31 to 69). All except two patients had a prosthetic aortic valve. Three patients had undergone aortic valve replacement twice. The indications for transesophageal echocardiography were known or suspected endocarditis in 14 patients, prosthetic valve dysfunction in 4, congestive heart failure in 1 and transient ischemic attack in 1. A definite diagnosis of endocarditis with positive blood cultures was made in 15 patients. Twelve of these 15 patients had active infection; the other 3 had been treated for endocarditis 6 months to 2 years earlier. Aortography was performed in 10 patients within 3.8 days (range 0 to 19) of the echocardiographic examination. In 7 of 10 patients,

Figure 1. Two-dimensional color flow Doppler and color M-mode examination of an unruptured intervalvular pseudoaneurysm from the transverse transesophageal plane. **Large arrow** points to the pseudoaneurysm. On the **two-dimensional images**, the transient flow filling the cavity is shown in early systole. In late systole, no detectable further flow is seen in the expanded pseudoaneurysm, whereas in diastole, the pseudoaneurysm collapses. **Dashed vertical line** shows the site of M-mode examination. **Color M-mode image** shows the timing of flow into and out of the pseudoaneurysm. **Small arrow on the left** shows flow into the pseudoaneurysm only during early systole; at onset of diastole, flow is seen from the pseudoaneurysm into the left ventricle (LV) (**small vertical arrow**). The pseudoaneurysm then collapses. LVO = left ventricular outflow; LA = left atrium; MAIVF = mitral-aortic intervalvular fibrosa pseudoaneurysm.

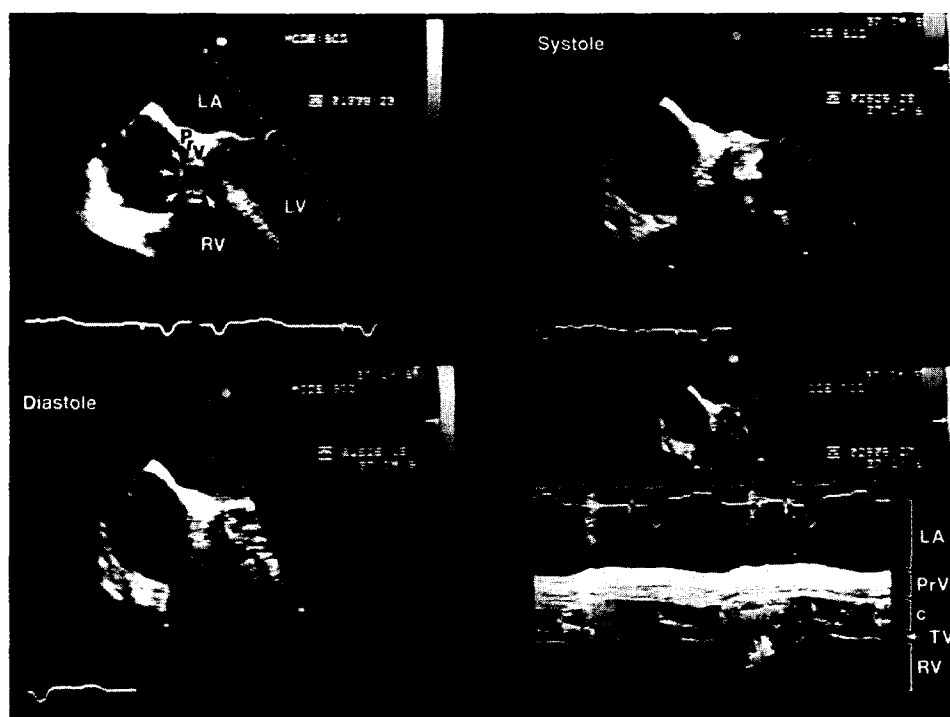


echocardiography preceded angiography. Eighteen of the 20 patients underwent surgical exploration and correction after the diagnostic studies.

Echocardiographic examination. After written informed consent had been obtained, all patients underwent transesophageal echocardiography using standard techniques (18). All 20

patients except 2 had a previous transthoracic study, along with color flow and Doppler examination. These studies were performed using either a Hewlett-Packard Sonos 1000 ultrasound system with 2.5-MHz transthoracic and 5-MHz monoplane and multiplane transesophageal probes or an Acuson 128 XP/10 imaging system with 2.5-MHz transthoracic and

Figure 2. Transesophageal two-dimensional color Doppler and M-mode images of an anterior ring abscess (arrows). Note the distance between the abscess and the mitral-aortic junction. **Color Doppler** shows flow in the abscess during both systole and diastole, the site of significant aortic insufficiency. The size of the abscess does not change significantly during the cardiac cycle. **Color M-mode** through the abscess shows continuous flow through the ring abscess and its constant size. c = abscess cavity; PrV = prosthetic valve; RV = right ventricle; TV = tricuspid valve; other abbreviations as in Figure 1.



5-MHz biplane transesophageal probes. Once a ring or intervalvular cavity lesion was visualized, it was further defined by subtle manipulations of the transducer or probe. These were aimed at optimizing the size of the cavity, defining its site in relation to adjacent structures and determining whether it communicated with other chambers. Blood flow in the lesion was evaluated by color Doppler, and timing was assessed with color M-mode echocardiography. All studies were recorded on 0.5-in. VHS videotapes.

Echocardiographic analysis. Studies were reviewed on an off-line station (Digisonics EC-500) interfaced with the video signal and equipped with a search module. These were reviewed by a single observer unaware of the clinical, angiographic or surgical data. The following characteristics were noted for each cavity lesion: site, appearance, size, pulsatility and communication with other chambers. An intervalvular pseudoaneurysm was defined as an echo-free cavity located posteriorly in the intervalvular fibrosa region just below the aortic annulus, along with communication with an adjacent cardiac chamber or presence of flow in the cavity, or both. A ring abscess was defined as a cavity at the level of the aortic annulus or sinuses of valsalva, sparing the intervalvular region, with or without involvement of the ascending aorta. Examples of an intervalvular pseudoaneurysm and aortic ring abscess are shown in Figures 1 and 2, respectively. The maximal area of the intervalvular pseudoaneurysm or ring abscess was determined by planimetry in both systole and diastole. Percent area change was calculated as the difference between systolic and diastolic areas divided by systolic area. The presence or absence of concomitant mitral or aortic insufficiency was noted and semiquantitated using conventional criteria (19,20).

Angiography. Aortic root cine angiography was performed in 10 patients with the Seldinger technique using 40 to 50 ml of contrast (Renografin 76). Nine of the 10 patients had a prosthetic aortic valve. The cineangiograms were obtained in the left anterior oblique projection in all 10 patients and in biplane projections in 6. In addition to the aortogram, a left ventriculogram was obtained in two patients after crossing the prosthetic aortic valve. Presence of an abscess or pseudoaneurysm was identified as opacification of a cavity in the aortic root or intervalvular region that was distinct from the sinuses of valsalva. If such a lesion was present, its location, pulsatility and filling pattern from the aorta or left ventricle were noted. An intervalvular pseudoaneurysm was defined as a posterior cavity that filled with contrast medium, located just below the aortic annulus, between the aortic ring and left atrium, with or without superior extension. Valvular regurgitation was assessed using conventional criteria (21). The angiographic studies were interpreted by an independent observer unaware of all other data.

Statistical analysis. Results are shown as mean value \pm SD. The detection of cavity lesions by the various modalities were compared using the Fisher exact test. The areas of ruptured and unruptured intervalvular pseudoaneurysms and ring abscesses as well as their change during the cardiac cycle

were compared using analysis of variance (Newman-Keuls test). Statistical significance was set at $p < 0.05$.

Results

Echocardiographic and Doppler studies. In the 20 patients studied, there were a total of 23 cavity lesions: 16 intervalvular pseudoaneurysms and 7 ring abscesses (Table 1). In two patients, both lesions were present. One patient had two nonadjacent ring abscesses. In the 21 cavity lesions imaged by both modalities, transthoracic echocardiography identified 9, whereas transesophageal echocardiography detected 19 ($p < 0.01$). In two cases, transesophageal echocardiography was equivocal despite multiplane imaging. These were ring abscesses located anteriorly and obscured by shadowing of the prosthetic valve; transthoracic echocardiography clearly identified these lesions. The echocardiographic and Doppler features of intervalvular pseudoaneurysms and ring abscesses are described next.

Intervalvular pseudoaneurysms. An intervalvular pseudoaneurysm appeared as a pulsatile echo-free pouch located posteriorly, in the intervalvular region, and bounded by the base of the anterior mitral leaflet, the medial wall of the left atrium and the posterior aortic root (Fig. 1). Transthoracic echocardiography detected 6 of the 16 intervalvular pseudoaneurysms and was suggestive in 1, whereas the transesophageal approach adequately visualized all 16 cases. The neck of all pseudoaneurysms opened to the left ventricular outflow through a dehiscence in the mitral-aortic continuity. This could not be seen by transthoracic echocardiography in any case. In contrast, it was visualized by transesophageal echocardiography in all patients and ranged from 0.5 to 2.1 cm in width. In two patients, septations were visualized within the cavity. In general, intervalvular pseudoaneurysms exhibited a distinct dynamic feature, expanding during isovolumic contraction and early systole and collapsing in diastole (Fig. 1). The maximal cavity area in systole averaged $4.1 \pm 3.4 \text{ cm}^2$ (range 0.7 to 12.5) and decreased in diastole to $1.8 \pm 2.2 \text{ cm}^2$ ($p < 0.05$) (Fig. 3, Table 1). In five cases, it was completely obliterated in diastole. The percent area change from systole to diastole ranged between 6% and 100% (mean $67 \pm 32\%$) (Table 1).

Using echocardiography and Doppler, two main types of intervalvular pseudoaneurysms could be discerned that exhibited different flow characteristics: unruptured pseudoaneurysms, communicating only with the left ventricular outflow tract, and ruptured pseudoaneurysms, with fistulous communication with either the left atrium or aorta. Of the 16 intervalvular pseudoaneurysms, 9 were unruptured and 7 were ruptured. The Doppler echocardiographic features are hereby described.

Unruptured intervalvular pseudoaneurysms. In early systole, an aliased flow of brief duration was seen in all nine cases, distending the pseudoaneurysm (Fig. 1). During mid to late systole, with the pseudoaneurysm maximally expanded, no significant further flow was seen. Subsequently, during early

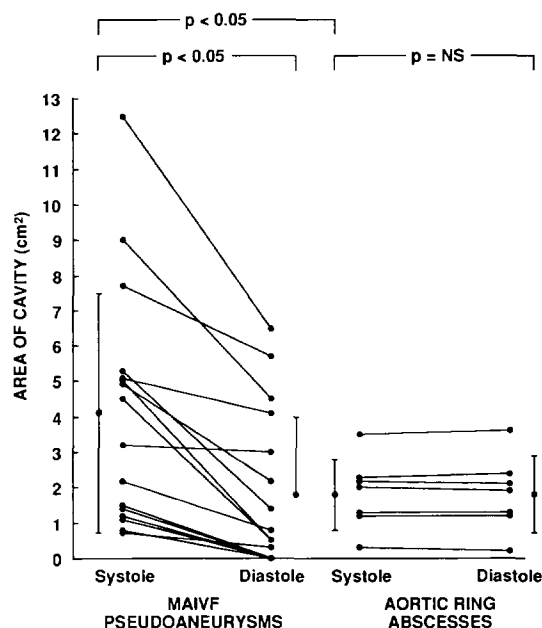


Figure 3. Comparison of intervalvular pseudoaneurysms and ring abscesses with respect to systolic cavity areas and change in area from systole to diastole. The intervalvular pseudoaneurysms have larger systolic areas and show greater change in cavity area from systole to diastole. MAIVF = mitral-aortic intervalvular fibrosa.

diastole, flow was seen emptying from the cavity into the outflow tract, concomitant with reduction in pseudoaneurysm size (Fig. 1). This flow was of low velocity compared with early systolic flow and could be clearly discerned in five of the nine cases. The use of color M-mode echocardiography, with its higher time resolution, better defined timing of flow.

Ruptured intervalvular pseudoaneurysms. Of the seven ruptured pseudoaneurysms, the fistulous communication was with the left atrium in three patients and with the aorta in four. This was in addition to the communication with the left ventricular outflow tract. In all cases communicating with the left atrium, a perforation in the pseudoaneurysm was seen by transesophageal echocardiography. Color flow Doppler showed severe eccentric "mitral" regurgitation (Fig. 4) through large perforations in the pseudoaneurysm in two patients and mild regurgitation in one. Tracking the origin of the regurgitant jet in fact facilitated the localization of the rupture site. None of the perforations were seen by transthoracic echocardiography. In one case, the transthoracic study showed eccentric regurgitation arising at a level superior to the mitral annulus. Similar to unruptured pseudoaneurysms, those communicating with the left atrium showed systolic expansion and diastolic collapse. However, on color Doppler echocardiography, the systolic flow through the pseudoaneurysm was intense and holosystolic.

In the four cases with rupture into the aorta, aortic insufficiency was detected. Although two lesions were identified by transthoracic echocardiography, they were best visualized with the transesophageal approach. In systole, color Doppler showed anterograde flow from the left ventricle through both

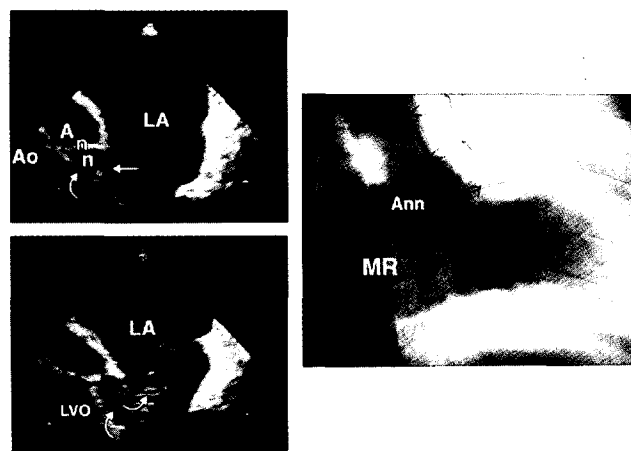
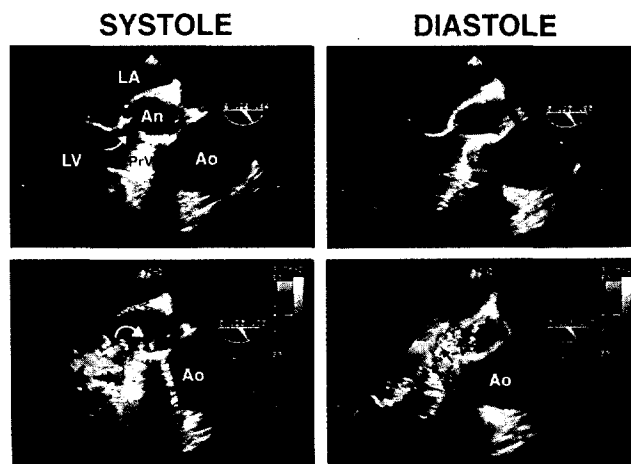


Figure 4. Left, Transesophageal two-dimensional (top) and color Doppler (bottom) images showing a mitral-aortic intervalvular fibrosa pseudoaneurysm (Ann) that has ruptured into the left atrium (LA). Curved arrow shows communication of the pseudoaneurysm with the left ventricular outflow (LVO) tract; straight arrow points to site of perforation. Color Doppler shows systolic flow from left ventricle to the pseudoaneurysm and then into the left atrium (curved arrows), producing "mitral" regurgitation. Right, Right anterior oblique view of left ventriculogram in the same patient showing the pseudoaneurysm and presence of mitral regurgitation (MR). The site of origin of the regurgitation is uncertain. Ao = aorta.

the pseudoaneurysm and the aortic valve into the aorta. In diastole, retrograde flow was seen directed from the aortic root into the pseudoaneurysm and ventricle (Fig. 5). In these cases, although pulsatility of the pseudoaneurysm was still seen during the cardiac cycle, it was less pronounced compared with

Figure 5. Two-dimensional and color Doppler frames during omniplane transesophageal examination at an angulation of 120° showing an intervalvular pseudoaneurysm (An) communicating with the aorta (Ao) and left ventricular outflow tract. During systole, blood flows into the pseudoaneurysm and from the pseudoaneurysm into the aorta through small fenestrations (white arrow). Black arrow points to the normal flow direction through the prosthetic valve (PrV). During diastole, blood regurgitates into the left ventricle (LV) through the pseudoaneurysm (black arrows). LA = left atrium.



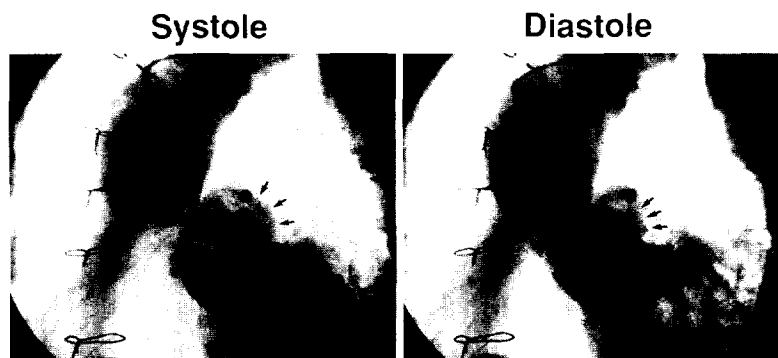


Figure 6. Left anterior oblique view during aortography in a patient with intervalvular pseudoaneurysm and aortic insufficiency. The intervalvular pseudoaneurysm is delineated by arrows and shows pulsatility during the cardiac cycle.

unruptured pseudoaneurysms (mean percent area of change $36 \pm 25\%$ vs. $75 \pm 28\%$, $p < 0.05$). None of the four cases had complete collapse of the pseudoaneurysm in diastole.

Aortic ring abscesses. Seven ring abscesses were detected by echocardiography in six patients. Four of the seven were anterior and three were posterior. The abscesses were usually confined to the aortic valve plane or extended further to the proximal aorta. Septations within the cavity were seen in three cases. Transthoracic echocardiography correctly identified three of seven abscesses, all of which were anterior. By contrast, transesophageal echocardiography identified five of seven lesions. The two cases where transthoracic imaging was superior to transesophageal imaging involved anterior lesions.

Compared with intervalvular pseudoaneurysms, ring abscesses exhibited different echocardiographic and Doppler features. The maximal systolic area of all seven abscesses averaged $1.85 \pm 1.03 \text{ cm}^2$ (range 0.26 to 3.5) and was significantly smaller than pseudoaneurysms ($4.1 \pm 3.4 \text{ cm}^2$, $p < 0.05$). Furthermore, ring abscesses did not exhibit significant expansion and collapse during the cardiac cycle (systolic area $1.85 \pm 1.03 \text{ cm}^2$ vs. diastolic area $1.83 \pm 1.07 \text{ cm}^2$, $p = \text{NS}$) (Fig. 2 and 3). Similarly, the percent change in cavity area from systole to diastole was significantly less ($3.4 \pm 8.7\%$ vs. $67.2 \pm 31.7\%$, respectively, $p < 0.05$). Color flow Doppler revealed either no flow through a walled-off abscess ($n = 3$) or both systolic and diastolic flow ($n = 4$), the site of severe paravalvular aortic insufficiency (Fig. 2).

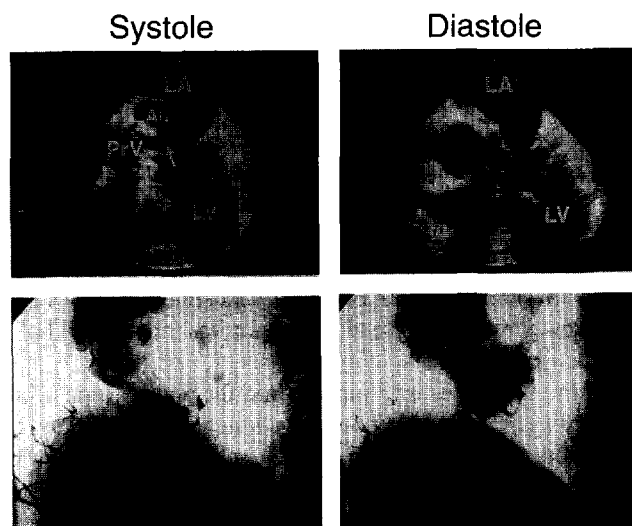
Angiographic findings. Of the 10 patients undergoing angiography, 9 had echocardiographic evidence of intervalvular pseudoaneurysms, and 1 had a ring abscess. Using aortography, the ring abscess was identified, and only two of nine intervalvular pseudoaneurysms could be demonstrated; both had concomitant aortic insufficiency (Fig. 6). In the remaining seven patients, aortographic results were normal (Table 1). None of these patients had aortic insufficiency. Transesophageal echocardiography in these patients showed an unruptured pseudoaneurysm in five and a ruptured pseudoaneurysm communicating with the left atrium in two. An example of a patient with a large intervalvular pseudoaneurysm that was missed at aortography is shown in Figure 7. In two of the seven patients with normal aortographic results, the intervalvular pseudoaneurysms were demonstrated with a separate contrast injec-

tion in the left ventricle after crossing the prosthetic aortic valve. Pseudoaneurysms identified at angiography exhibited pulsatility during the cardiac cycle, similar to that observed with echocardiography.

Surgical findings and outcome. Eighteen of the 20 patients underwent surgical repair. The findings at operation are shown in Table 1. Surgical intervention was performed on the sole basis of echocardiographic findings in 13 patients and both echocardiographic and angiographic findings in 5. All positive diagnoses of pseudoaneurysms or ring abscesses by echocardiography or angiography were confirmed at operation. The seven cases of pseudoaneurysms missed at aortography were identified at operation.

Of the 18 patients undergoing surgical repair, 16 already had a prosthetic aortic valve. Surgical repair consisted of excision of the abscess or pseudoaneurysm and aortic valve

Figure 7. Images from a patient with an unruptured intervalvular pseudoaneurysm diagnosed at transesophageal echocardiography and missed at aortography. **Top,** Transesophageal transverse planes showing the intervalvular pseudoaneurysm (An) expanding during systole (left) and collapsing during diastole (right). Arrow points to the communication between the pseudoaneurysm and left ventricular outflow. **Bottom,** Aortograms during systole and diastole in the same patient appear normal.



replacement. In five patients, the pathologic condition necessitated an aortic root replacement with a composite graft ($n = 4$) or a homograft ($n = 1$). Overall, identification of intervalvular pseudoaneurysms preoperatively helped guide the surgical approach. Because of the location of the pseudoaneurysm between the aorta and left atrium and its relatively small size, it is not readily visualized through the aortotomy site. In the two cases of pseudoaneurysm and left atrial communication, the perforation was closed and the native mitral valve left intact. In one of these two cases where angiography was available and preceded echocardiography, the planned mitral valve replacement was modified after the transesophageal study identified the etiology of mitral regurgitation.

Of the 18 patients who underwent surgical repair, 1 patient with a ruptured pseudoaneurysm communicating with the aorta died in-hospital. Two patients with pseudoaneurysms, one unruptured and the other with a small perforation and mild mitral regurgitation, refused surgical repair. Both were alive and asymptomatic 1 year later.

Discussion

This study details the echocardiographic and Doppler characteristics of cavitory lesions complicating aortic valve disease. Pseudoaneurysms involving the intervalvular fibrosa region exhibited phasic changes during the cardiac cycle and characteristic flow patterns that were different from ring abscesses. Overall, transesophageal echocardiography was superior to transthoracic examination and to aortography in identifying intervalvular pseudoaneurysms.

Involvement of the intervalvular fibrosa. Involvement of the aortic annulus is common in aortic valve endocarditis, particularly in patients with prosthetic valves (1-3). Such perivalvular extension is associated with worse prognosis (22). The region of aortomitral continuity or intervalvular fibrosa, which contains fibrous, relatively avascular tissue, is the weakest segment of the aortic ring (23). Its roof is formed by the pericardium and inferiorly it is related to the left ventricular outflow tract. The intervalvular region has been noted to be prone to infection, which may result in a variety of abnormalities, including abscesses and pseudoaneurysms, with or without perforation into the left atrium or pericardial space (5,7,11,14,15,24). In the present study, which we believe includes the largest reported series of cavitory lesions complicating the aortic root, intervalvular involvement was seen in the majority (69%) of cases, further confirming earlier reports. In the overall evaluation of these cavities, it is imperative to assess the presence of concomitant communications with adjacent cardiac chambers that help define the etiology of associated regurgitant lesions and ultimately guide appropriate surgical therapy.

Detection and dynamic characterization with echocardiographic and Doppler techniques. Transthoracic echocardiography has been used for the diagnosis of aortic root complications (25,26). However, its sensitivity has been recently shown to be limited in the evaluation of posterior lesions, particularly

in the presence of prosthetic aortic valves. Transesophageal echocardiography has been shown to substantially improve the diagnosis of such lesions (13,16). In the present series, transesophageal echocardiography was superior to transthoracic imaging in the detection of intervalvular pseudoaneurysms and posterior ring abscesses. However, the importance of the transthoracic approach in anterior ring abscesses cannot be ignored, particularly in the presence of prosthetic aortic valves, where transesophageal echocardiography may have significant limitations because of shadowing of the prosthesis, as illustrated in this study. Thus, combined transthoracic and transesophageal imaging would allow a comprehensive evaluation of the aortic root, particularly in prosthetic aortic valves.

Compared with ring abscesses, intervalvular pseudoaneurysms were larger and exhibited a characteristic feature during the cardiac cycle, namely marked pulsatility, expanding in early systole and collapsing in diastole. A feature of intervalvular pseudoaneurysm, as opposed to a mere abscess in the intervalvular region, is its communication with the left ventricular outflow tract and hence flow into the cavity. The pressure in the pseudoaneurysm is therefore similar to that of the left ventricle. During isovolumic contraction and early systole, pressure in the pseudoaneurysm exceeds left atrial pressure. Blood then flows into the intervalvular cavity expanding it, as demonstrated by color Doppler. During diastole, as pressure in the left ventricle and, therefore, the pseudoaneurysm, decreases below left atrial pressure, the pseudoaneurysm, bounded in large part by the left atrial wall, collapses. In pseudoaneurysms communicating with the aorta, the pulsatility was less marked. Impingement of the aortic insufficiency jet on the walls of the pseudoaneurysm or the presence of elevated ventricular diastolic pressure, or both, may account for this finding.

The lack of pulsatility of ring abscesses may be explained by several factors. In abscesses that did not communicate with any chamber and no flow could be detected, significant collapsibility of the walled-off abscess is not expected. In ring abscesses with systolic and diastolic flow, the site of paravalvular regurgitation, these abscesses were at the level of the aortic annulus and extended into the ascending aorta and were thus exposed predominantly to aortic pressure. In these cases, the higher pressure in the abscess throughout the cardiac cycle compared with that of adjacent chambers, such as the right ventricle, left atrium or pulmonary artery, may explain the lack of collapsibility of ring abscesses.

The application of color Doppler imaging was crucial, not only in characterizing flow and helping to explain the dynamic changes of the cavities during the cardiac cycle, but also in defining their communications to adjacent cardiac chambers. The site of communication was usually better defined after delineation of the origin of the color flow jet into the adjacent chamber and focusing subsequently on imaging. Previous studies have demonstrated use of color Doppler in identifying rupture of intervalvular aneurysms into the left atrium (9,14,16). There have been reports of aneurysms where concomitant aortic insufficiency was noted (11,14,16,30). Whether

the aortic insufficiency was valvular or due to rupture of intervalvular fibrosa into the aorta was not clarified. In this report, the application of color M-mode echocardiography in the assessment of timing of flow in and out of unruptured aneurysms helped us to understand their dynamic behavior. Although the present study cannot assess the sensitivity of echocardiographic techniques in the evaluation of intervalvular pseudoaneurysms or ring abscesses, the combination of transthoracic and transesophageal imaging allowed a comprehensive anatomic and hemodynamic evaluation of these complex lesions that was confirmed at surgical repair.

Role of angiography. In the past, cine angiography has been the standard for diagnosing aortic root lesions (27). Few cases have been described demonstrating intervalvular pseudoaneurysms with angiography (7,10,24). We believe that the present series is the first to report a comparison of aortographic and echocardiographic findings in patients with intervalvular pseudoaneurysms who underwent surgical exploration. With the use of aortography, only two of nine pseudoaneurysms were identified, both with associated aortic insufficiency. Because of the presence of prosthetic aortic valves, a separate left ventriculogram was performed in only two cases, demonstrating the intervalvular pseudoaneurysm. Reported cases where angiography demonstrated an intervalvular pseudoaneurysm have involved left ventriculography (10,12,24). A case where a pseudoaneurysm was seen on aortography was associated with severe aortic insufficiency (7). The direct communication between the left ventricular outflow tract and the pseudoaneurysm explains the need for a ventricular injection of dye, in the absence of aortic insufficiency, to detect this abnormality. Compared with angiography, transesophageal echocardiography in this study more clearly delineated the origin of intervalvular pseudoaneurysms and their communication. In a patient with ruptured pseudoaneurysm and mitral regurgitation at angiography, transesophageal echocardiography elucidated the etiology of mitral regurgitation as a perforation in the pseudoaneurysm and altered the planned surgical therapy for mitral valve replacement.

Etiology and management of intervalvular pseudoaneurysms. The majority of lesions in the region of the intervalvular fibrosa are secondary to infection and are more common in patients with prosthetic valves (5,11,14,16,28). Other reported etiologies include trauma and congenital pseudoaneurysms (9,29). Although the majority of patients in our series had active endocarditis, 5 of the 16 had no recent or remote evidence of infection. All had previously undergone aortic valve replacement, and three had undergone a second aortic valve replacement. Although a remote subclinical and self-limiting endocarditis cannot be excluded, this finding suggests a role for surgical trauma in the pathogenesis of some intervalvular pseudoaneurysms.

Patients with cavitary lesions complicating aortic valve disease, particularly prosthetic valves, may require extensive surgical intervention, including, in some cases, aortic root replacement, as shown in the present series. However, the natural history of uncomplicated pseudoaneurysms is unclear.

In most reported cases, surgical repair followed diagnosis (10,14,16,30). In one patient with a 4-year follow-up period, the intervalvular pseudoaneurysm had no change in size (30). Two patients in our series refused surgical repair and were alive 1 year later. However, because of the risk of possible rupture into the pericardium, surgical correction of intervalvular pseudoaneurysms is probably warranted in the majority of cases. In patients not undergoing immediate operation, transesophageal echocardiography may be useful to identify serial changes in size or development of communications with adjacent chambers, which may help plan appropriate therapy.

Conclusions. Intervalvular pseudoaneurysms are detected more frequently with transesophageal echocardiography compared with transthoracic echocardiography and aortography. Characteristic dynamic features and flow patterns can be identified. The combined use of transthoracic and transesophageal echocardiography, along with color Doppler, allows the identification and characterization of cavitary lesions involving the aortic root and provides information that can be essential in guiding appropriate surgical therapy.

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References

1. Arnett EN, Roberts WC. Valve ring abscess in active infective endocarditis: frequency, location and clues to clinical diagnosis from the study of 95 necropsy patients. *Circulation* 1976;54:140-5.
2. Arnett EN, Roberts WC. Prosthetic valve endocarditis: clinico-pathologic analysis of 22 necropsy patients with comparison of observations in 74 necropsy patients with active infective endocarditis involving natural left sided cardiac valves. *Am J Cardiol* 1976;38:281-92.
3. Guiterrez PS, Mansur AJ, Peranovich JOS. Cavitary lesions close to heart valve rings: a necropsy study of 13 patients. *J Cardiovasc Surg* 1991;32:259-64.
4. Gross L, Kugel MA. Topographic anatomy and histology of the valves in the human heart. *Am J Path* 1931;7:445-73.
5. Chesler E, Korn ME, Porter GE, Reyes CN, Edwards JE. False aneurysm of the left ventricle secondary to bacterial endocarditis with perforation of the mitral-aortic intervalvular fibrosa. *Circulation* 1968;37:518-23.
6. Edward JE, Burchell HB. The pathological anatomy of deficiencies between the ring and the heart including aortic sinus aneurysms. *Thorax* 1957;12:125-39.
7. Layman TE, January LE. Mycotic left ventricular aneurysm involving the fibrous atrioventricular body. *Am J Cardiol* 1967;20:423-7.
8. Qizilbash AH, Schwartz CJ. False aneurysm of left ventricle due to perforation of mitral-aortic intervalvular fibrosa with rupture and cardiac tamponade. *Am J Cardiol* 1973;32:110-3.
9. Taliencio CP, Oh JK, Summerer MH, Butler CF, Danielson GK. Traumatic left ventricular false aneurysm with significant regurgitation from left ventricular outflow tract to left atrium: delineation by two-dimensional and color flow Doppler echocardiography. *J Am Soc Echocardiogr* 1988;1:354-8.
10. Waldhausen JA, Petry EL, Kurlander GJ. Successful repair of subvalvular annular aneurysm of the left ventricle. *N Engl J Med* 1966;275:984-7.
11. Bansal RC, Moloney PM, Marsa RJ, Jacobson JG. Echocardiographic features of a mycotic aneurysm of the left ventricular outflow tract caused by perforation of mitral-aortic intervalvular fibrosa. *Circulation* 1983;67:930-4.
12. Akins WE, Limacher M, Slone RM, Hill JA. Evaluation of an aortic annular pseudoaneurysm by MRI: comparison with echocardiography, angiography and surgery. *Cardiovasc Intervent Radiol* 1987;10:188-93.
13. Daniel WG, Mügge A, Martin RP, et al. Improvement in the diagnosis of

- abscesses associated with endocarditis by transesophageal echocardiography. *N Engl J Med* 1991;324:795-800.
14. Karalis DG, Bansal RC, Hauck AJ, et al. Transesophageal echocardiographic recognition of subaortic complications in aortic valve endocarditis: clinical and surgical implications. *Circulation* 1992;86:353-62.
15. Fisher EA, Estioko MR, Stern EH, Goldman ME. Left ventricular to left atrial communication secondary to a paraaortic abscess: Color flow Doppler documentation. *J Am Coll Cardiol* 1987;10:222-4.
16. Bansal RC, Graham BM, Jutzy KR, Shakudo M, Shah PM. Left ventricular outflow tract to left atrial communication secondary to rupture of mitral-aortic intervalvular fibrosa in infective endocarditis: diagnosis by transesophageal echocardiography and color flow imaging. *J Am Coll Cardiol* 1990;15:499-504.
17. Barbetseas J, Crawford ES, Safi HJ, Coselli JS, Quiñones MA, Zoghbi WA. Doppler echocardiographic evaluation of pseudoaneurysms complicating composite grafts of the ascending aorta. *Circulation* 1992;85:212-22.
18. Seward JB, Khandheria BK, Oh JK, et al. Transesophageal echocardiography: technique, anatomic correlations, implementation and clinical applications. *Mayo Clin Proc* 1988;63:649-80.
19. Smith MD. Evaluation of valvular regurgitation by Doppler echocardiography. *Cardiol Clin* 1991;9:193-228.
20. Yoshida K, Yoshikawa J, Yamaura Y, Hozumi T, Akasaka T, Fukaya T. Assessment of mitral regurgitation by biplane transesophageal color Doppler flow mapping. *Circulation* 1990;82:1121-6.
21. Grossman W, Baim DS, editors. *Cardiac Catheterization, Angiography, and Intervention*. Philadelphia: Lea & Febiger, 1991:557-81.
22. John RM, Pugsley W, Treasure T, Sturridge MF, Swanton RH. Aortic root complications of infective endocarditis-influence on surgical outcome. *Eur Heart J* 1991;12:241-8.
23. Allworth SP. The anatomical basis of infection of the ring. *Thorac Cardiovasc Surg* 1986;34:143-8.
24. Reid CL, McKay C, Kawanishi DT, Edwards C, Rahimtoola SH, Chandraratna PAN. False aneurysm of mitral-aortic intervalvular fibrosa: diagnosis by 2-dimensional contrast echocardiography at cardiac catheterization. *Am J Cardiol* 1983;51:1801-2.
25. Russo G, Tamburino C, Greco G, et al. Echocardiographic detection of aortic valve ring abscesses. *J Ultrasound Med* 1990;9:319-23.
26. Saner HE, Asinger RW, Homans DC, Helseth HK, Elsparger KJ. Two-dimensional echocardiographic identification of complicated aortic root endocarditis: implications for surgery. *J Am Coll Cardiol* 1987;10:859-68.
27. Miller SW, Dinsmore RE. Aortic root abscess resulting from endocarditis: spectrum of angiographic findings. *Radiology* 1984;153:357-61.
28. Schwartz DR, Belkin RN, Pucillo AL, et al. Aneurysm of the mitral aortic intervalvular fibrosa complicating infective endocarditis: preoperative characterization by two dimensional and color flow Doppler echocardiography, magnetic resonance imaging, and cineangiography. *Am Heart J* 1990;119:196-9.
29. Chesler E, Joffe N, Schamroth L, Meyers A. Annular subvalvular left ventricular aneurysms in the South African Bantu. *Circulation* 1965;32:43-51.
30. Meyerowitz CB, Jacobs LE, Kotler MN, Loli AW, Wertheimer JH. Four year follow-up of a pseudoaneurysm of the mitral-aortic fibrosa. *Am Heart J* 1991;122:589-92.